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Oldenburg Discussion Papers in Economics

Why is Satisfaction from Pro-Environmental Behaviors Increasing in Costs? Insights from the Rational-Choice Decision-Error Framework

Heinz Welsch

V – 441-23

May 2023

Department of Economics
University of Oldenburg, D-26111 Oldenburg

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Heinz Welsch
Department of Economics
University of Oldenburg
26111 Oldenburg, Germany
welsch@uni-oldenburg.de

Abstract

The literature on subjective well-being (SWB) and the environment has found robust evidence of positive net marginal SWB from pro-environmental behavior (PEB), that is, positive marginal SWB net of the associated costs in terms of money, time and effort (Finding 1). Accordingly, people could increase their SWB (utility) by behaving more pro-environmentally. In addition, net marginal SWB was found to be larger with respect to more costly than with respect to less costly PEBs (Finding 2). Finding 1 is at odds with rational choice theory's demand that marginal utility be equalized with marginal costs, that is, net marginal utility be zero. The finding can be (and has been) explained by decision error, that is, a failure in forecasting the well-being consequences of an act of choice. This paper uses the rational-choice decision-error framework to show that if (i) observed levels of PEB are the result of rational choice and (ii) there is positive net marginal SWB at observed PEB levels due to decision error, then net marginal SWB from a PEB is increasing in its marginal costs. The ability of the rational-choice decision error framework to explain not only Finding 1 but Finding 2 provides empirical support for that framework.

Keywords: pro-environmental behavior; subjective well-being; decision error; rational choice; affective forecasting

JEL codes: Q21; I31; D90; D11; D12

1. Introduction

A considerable literature has studied the relationship between subjective well-being (SWB) and pro-environmental behavior (PEB) and has typically found that (1) higher levels or intensities of PEB are related to greater SWB and (2) the relationship between PEB and SWB is stronger and/or more significant with respect to more costly than with respect to less costly behaviors.[1] For example, Schmitt et al. (2018) found that 37 out of 39 PEBs were significantly related with greater life satisfaction and that the strength of the relationship was highly correlated (at $r = 0.74$) with the respective behaviors' costs in terms of money, time or effort.[2] Haverkamp et al. (2022) found SWB to be significantly positively correlated to costly PEBs but not to costless or low-cost PEBs.

Both of these findings are surprising and difficult to explain from the point of view of standard economic (rational choice) theory. With respect to Finding 1, the pertinent empirical studies typically use specifications that involve the marginal well-being (satisfaction) from PEB *net* of the associated marginal costs (Welsch 2020), and find it to be positive, whereas rational choice demands that, at the utility-maximizing level of PEB, net marginal utility be zero.

To explain positive net marginal well-being against this background, a divergence has been invoked between *experienced utility*, the ex-post hedonic quality of (or satisfaction from) an act of choice, and *decision utility*, the ex-ante expectation of experienced utility (Kahneman et al. 1997): Due to a failure in affective forecasting (Loewenstein et al. 2003, Wilson and Gilbert 2003), it is argued, people ex ante underrate the satisfaction they will derive from choosing an environment-friendly good relative to the satisfaction from "conventional" consumption. This leads to decision error in that the chosen levels of PEB are less than optimal ex post, and people could raise their satisfaction by behaving more environment-friendly (Welsch and Kühling 2010, 2011).

[1] Positive relationships between SWB and a large variety of PEBs were found in data from Canada, China, Germany, Mexico, Spain, Sweden, the U.K. and the U.S. as well as in multi-country data sets. Pertinent papers include Brown and Kasser (2005), Videras and Owen (2006), Jacob et al. (2009), Welsch and Kühling (2010, 2011), Corral-Verdugo et al. (2011), Xiao and Li (2011), Kaida and Kaida (2016), Kühling (2014), Suarez-Varela et al. (2016), Schmitt et al. (2018) and Laffan (2020). See Welsch (2020) for a survey.

[2] Schmitt et al. (2018) provide examples of PEBs that require time and effort (e.g., sorting recycling), cost money (e.g., eating organic food rather than conventionally grown), or require an initial financial investment (e.g., buying energy efficient appliances). Pro-environmental behavior can also be inconvenient or involve personal sacrifice (e.g., public transit does not provide door-to-door transportation as driving a privately-owned automobile does). Other PEBs save money (e.g., reduced electricity use), time (e.g., taking shorter or fewer showers), or effort (doing only full loads of laundry).

To explain Finding 2, it has been suggested that more costly PEBs may be more strongly related to SWB because people enjoy moral satisfaction from (are proud of) contributing their own resources or because they perceive costly behaviors to be more efficacious in helping the environment (Schmitt et al. 2018). However, these explanations are ad hoc and relatively speculative in comparison to explanations of other factors that were found to moderate the PEB-SWB relationship, such as the degree to which behaviors are observed by others (e.g., driving an e-car) and the degree to which they involve social interaction (e.g., participating in an environmental group). Different from the cost moderator, the moderating role of observability and opportunities for socializing can be explained by drawing on established literature.[3]

This paper addresses the question of why the satisfaction from pro-environmental behavior is increasing in costs from a different angle. It shows that the decision-error explanation of Finding 1 provides an explanation of Finding 2 as well. Specifically, adding systematic (non-random) decision error to rational choice theory, the paper shows that if (i) observed levels of PEB are the result of rational choice and (ii) there is positive net marginal SWB at observed PEB levels (due to decision error), then the net marginal SWB from a PEB is increasing in its marginal costs. Furthermore, it argues that the ability of the rational-choice decision-error framework to explain not only Finding 1 but Finding 2 provides empirical support for that framework.

2. Rational Choice and the Empirical SWB-PEB Relationship

Let g denote the quantity of an environment-friendly consumption good, c its conventional counterpart, p the price (cost) of g relative to c, and y exogenous income. An individual i is assumed to maximize an increasing and strictly concave decision utility function $\widetilde{U}(g_i, c_i)$ subject to the budget constraint $c_i = y_i - pg_i$.

By inserting the budget constraint into the utility function, one gets a semi-reduced utility function in p, y_i, and g_i:

$$\widetilde{U}(g_i, y_i - pg_i) =: U(p, y_i, g_i).$$

[3] The positive correlation of the behavior-satisfaction gradient with observability is explicable in terms of the prestige and reputation conveyed by some pro-environmental behaviors (Harbaugh 1998, Sexton and Sexton 2014). The correlation with opportunities for social interaction is consistent with findings that people report the highest levels of well-being when socializing or connecting with other people (Kahneman et al. 2004).

Given the strict concavity of the original utility function, $\widetilde{U}(g_i, c_i)$, the semi-reduced form $U(p, y_i, g_i)$ is hill-shaped in g_i. An interior utility maximum is then characterized by the first-order condition

$$U_g := \frac{dU}{dg_i} = \frac{\partial \widetilde{U}}{\partial g_i} - p\frac{\partial \widetilde{U}}{\partial c_i} = 0, \quad (1)$$

which tells us that at the utility maximum the (gross) marginal utility from the environment-friendly good equals the marginal disutility from reduced conventional good consumption times the cost (in terms of the conventional good) of the environment-friendly good.

In a more general sense, g_i can be interpreted as any pro-environmental behavior that involves a cost in terms of money, time or effort at the expense of some other "conventional" behavior. In any case, people choose the level or intensity of a PEB such as to attain an optimal tradeoff between benefits and costs, which implies zero net marginal utility: $U_g = 0$.

The latter condition stands in stark contrast to typical findings from empirical research on the PEB-SWB relationship. Disregarding simple correlation analyses, this research involves regression equations of the form

$$SWB_i = a + b^*g_i + c^*y_i + d^*controls_i + e_i,$$

where $controls_i$ is a vector of the usual correlates of SWB and e_i is an error term. The constant a captures factors common to all individuals (in particular the cost parameter p). SWB is thus specified as a function of p, y_i and g_i ,and the estimating equation can be taken to be a linearized version of the semi-reduced utility function $U(p, y_i, g_i)$. The crucial parameter is b. This parameter measures the *net* marginal utility of pro-environmental behavior, that is, the derivative of $U(p, y_i, g_i)$ with respect to g_i. While the parameter should be zero according to the rational choice (utility maximization) assumption (equation 1), it has been found to be significantly positive for a large set of behaviors. This means that the existing evidence is inconsistent with the rational choice model of pro-environmental behavior (Welsch and Kühling 2010, 2011). In terms of the theoretical model, the evidence suggests that people end up on the left-hand, rising branch of the hill-shaped behavior-utility schedule, rather than on the top of the utility hill. As a consequence, they could increase their utility by behaving in a more environmentally-friendly manner.

3. Decision Error and Pro-Environmental Behavior

There are several possible explanations of why empirical studies have found net marginal utility of pro-environmental behavior to be positive – in contradiction to the rational choice model.[4] A major explanation is decision error. It relies on the distinction between decision utility and experienced utility introduced by Kahneman et al. (1997). Experienced utility – measured by subjective well-being – is the *ex post* hedonic quality (satisfaction) associated with an act of choice whereas decision utility is the *ex ante* expectation of experienced utility.

Given the conceptual distinction between the two notions of utility, an important issue is whether or not the decision utility function and the experienced utility function coincide, that is, whether people know and correctly apply their experienced utility function when making economic choices or rather make systematic errors. As will be seen shortly, available evidence suggests that there may be systematic decision errors to the disadvantage of intrinsically motivated choices, such as pro-environmental consumption.

A major reason for decision errors to occur is that people adapt to consumption levels attained but fail to correctly anticipate this adaptation when taking consumption decisions, due to a failure in affective forecasting (Wilson and Gilbert 2003, Loewenstein et al. 2003). In addition, people evaluate their consumption level relative to that of others and fail to anticipate increases in comparator consumption that undermine the satisfaction they will experience (Clark et al. 2008).

While adaptation is well established with respect to consumption (Clark et al. 2008), such adaptation does not seem to apply to all sorts of activities and outcomes alike. Especially, people do not seem to adapt their utility evaluation in the case of outcomes which relate to intrinsic motivations, as opposed to extrinsic motivations (e.g., Stutzer and Frey 2008). In the case of intrinsic motivation, utility derives from an internal reward as a direct result of a particular activity or choice, e.g. the "warm glow" (Andreoni 1990). In the case of extrinsic motivation, choice is instrumental to some external goal such as acquisition, possession, and status.

Since failures of affective forecasting result from failures to anticipate hedonic adaptation, and since hedonic adaptation is more important for some categories of outcomes than for others,

[4] This section draws on Welsch (2020).

it follows that some sorts of outcomes are more likely to involve inaccurate utility forecasting than others. This asymmetry in the accuracy of utility forecasting is the origin of distorted, non-utility-maximizing choice. Especially, it implies that choice is distorted towards extrinsically motivated choices, such as consumption, relative to activities which serve less material goals. Consistent with such reasoning, Stutzer and Frey (2008) found that people systematically overestimate the value of the things they will obtain by commuting – more money, more material goods, more prestige – and underestimate the benefit of what they are losing: social connections, hobbies, and health.

Assuming that pro-environmental consumption is more intrinsically motivated than "conventional" consumption, this reasoning suggests that, when facing a PEB-consumption tradeoff, people choose levels of pro-environmental behavior that are less than optimal *ex post*, that is, people could achieve an increase in net experienced utility by behaving in a more environmentally-friendly manner (Welsch and Kühling 2010, 2011). In this sense, decision error due to asymmetric unforeseen hedonic adaptation provides a possible explanation for the evidence of a positive net marginal utility from pro-environmental behaviors.[5]

4. Costs and the Satisfaction from Pro-Environmental Behavior

This section studies how net marginal experienced utility (SWB) of a PEB depends on the costs of that PEB if people successfully maximize their decision utility function. The decision and experienced utility functions are specified as constant-elasticity-of-substitution (CES) functions, that is, functions for which $\sigma = -\frac{\partial \ln\left(\frac{g}{c}\right)}{\partial \ln p}$ is constant.[6]

We start with the special case $\sigma = 1$, that is, the Cobb-Douglas function. Omitting the person index i, the (reduced-form) decision utility function is specified as

[5] The idea that positive net marginal utility of pro-environmental behavior may be due to decision errors is supported by evidence that the behavior-satisfaction gradient is smaller in better educated people and larger in people with more materialistic values, on the presumption that more materialistic, extrinsically motivated individuals are more likely to overrate ex ante the well-being benefits from consumption (Welsch and Kühling 2010). Further evidence supporting the decision-error hypothesis is that the PEB-satisfaction gradient is smaller in people who have engaged in these behaviors for a longer time, as this may have helped them to learn their experienced utility function and bring their decision utility function more in line with it (Welsch and Kühling 2011). In addition, Welsch and Kühling (2011) found no statistically significant association between well-being and buying organic food (in contrast to low-energy light bulbs and household appliances), and explained this by the likely dominance of non-intrinsic motives (relating to taste and perceived healthiness) in the purchase of organic food.

[6] The elasticity of substitution, σ, is the percentage change of g/c following from a 1-percent increase in p (the price of g relative to the price of c, the latter being unity in the current case).

$$U(p, g, y) = \alpha \ln(g) + (1 - \alpha) \ln(y - pg).$$

Its experienced utility counterpart is

$$V(p, g, y) = \beta \ln(g) + (1 - \beta) \ln(y - pg).$$

In these specifications, $\alpha \in (0,1)$ and $\beta \in (0,1)$ are the weights placed on PEB relative to conventional consumption, *c*, in the decision and experienced utility functions, respectively.

Maximization of the decision utility function with respect to *g* yields the optimal levels of *g* and, by using the budget constraint, *c*:

$$g^* = \alpha y/p \text{ and } c^* = y - pg^* = (1 - \alpha)y.$$

It will first be studied under what conditions net marginal experienced utility of *g* at g^* is positive, before considering the role of costs.

Net marginal experienced utility at g^* is

$$W(g^*) := \frac{dV}{dg}(g^*) = \frac{\beta}{g^*} - p\frac{1-\beta}{y-pg^*} = \frac{\beta}{\alpha y/p} - p\frac{1-\beta}{(1-\alpha)y} . \tag{2}$$

Straightforward manipulations show that

$$sgn\, W(g^*) = sgn\, (\beta - \alpha). \tag{3}$$

Net marginal experienced utility at g^* is thus positive if and only if the weight placed on *g* in the decision utility function is less than the weight placed on *g* in the experienced utility function or, equivalently, if the weight placed on *c* in the experienced utility function is less than the weight placed on *c* in the decision utility function. It is also evident from equation (2) that $W(g^*)$ increases in β and decreases in α. A larger weight on *g* in the decision utility function (α) thus implies smaller net marginal experienced utility of *g*.

As shown in the Appendix, the same result is obtained when, retaining the interpretation of α and β as utility weights, the decision and experienced utility functions are specified as constant-elasticity-of-substitution (CES) functions with identical values $\sigma \neq 1$ for the decision and experienced utility functions. We thus have the following

Proposition 1: Positive net marginal experienced utility of PEB arises if (i) people successfully maximize decision utility and (ii) the weight on PEB relative to conventional consumption in the experienced utility function is greater than the corresponding weight in the decision utility function.

As noted before, a greater relative weight on PEB in the experienced utility function than in the decision utility function (condition ii) is equivalent to a smaller relative weight on conventional consumption in the experienced than in the decision utility function. Referring to the discussion in section 3, the latter may reflect the phenomenon that the satisfaction arising from conventional consumption (relative to the satisfaction from PEB) is overrated ex ante and turns out to be less than expected due to a failure in adequately anticipating adaptation and comparator consumption effects.

Turning to the role of the costs of PEB, we again start with the Cobb-Douglas case. Rewrite equation (2) as follows:

$$W(g^*) = p\left(\frac{\beta}{\alpha y} - \frac{1-\beta}{(1-\alpha)y}\right) .$$

This shows that the sign of the derivative of $W(g^*)$ with respect to p equals the sign of $W(g^*)$, which depends on the utility weights α and β as stated in equation (3). In particular, the net marginal experienced utility $W(g^*)$ increases in p whenever $\beta > \alpha$.

The case $\sigma \neq 1$ is technically more difficult to handle than the Cobb-Douglas case as, in contrast to the latter, it involves cross-price effects.[7] As shown in the Appendix, the sign of the derivative of net marginal experienced utility of g, $W(g^*)$, with respect to p depends on whether g and c are substitutes or complements. The results are summarized by

[7] As stated above, the optimal level of c in the Cobb-Douglas case is $c^* = y - pg^* = (1-\alpha)y$, which is independent of p (since with $\sigma = 1$ substitution and income effects of p on c just cancel).

Proposition 2: If, due to conditions (i) and (ii) stated in Proposition 1, net marginal experienced utility of PEB is positive, then it increases in the costs of PEB if the elasticity of substitution between the PEB and its conventional counterpart is greater than or equal to unity.

It should be noted that the "if" clause in this proposition specifies a sufficient, not a necessary condition for the net marginal experienced utility of a PEB to increase in its costs. As discussed in the Appendix, net marginal experienced utility of a PEB can also increase in costs for sufficiently weak degrees of complementarity between the PEB and conventional consumption.

5. Discussion and Conclusion

This paper has shown that the rational-choice *cum* decision-error framework provides a consistent explanation for the empirical findings that engaging in pro-environmental behaviors yields positive net marginal SWB and that net marginal SWB is increasing in the behaviors' costs in terms of money, time or effort.

The intuition behind these findings is straightforward: First, under rational choice, net marginal decision utility of a PEB is zero whereas net marginal experienced utility is positive – provided that the weight on the PEB in the experienced utility function is greater than the weight in the decision utility function. Second, a higher cost of PEB leads to a lower level of PEB being carried out, and the latter translates into smaller net marginal SWB from the PEB due to concavity of the experienced utility function.

The analysis has shown that for higher costs to lead to greater net marginal SWB, a PEB and its conventional counterpart must be sufficiently substitutable for each other. The intuition here is that higher costs do *not* increase the choice distortion between g and c if the two are strong complements: higher costs then reduce the level of *both* the PEB and the conventional good. Strong complementarity between a PEB and its conventional counterpart is, however, not very likely. For example, eating organic food and conventionally grown food are (imperfect) substitutes, rather than complements for each other. Similarly, public transit is a substitute for driving a privately-owned automobile, even if an imperfect one. In both cases, the PEB and its counterpart may be combined in varying proportions depending on relative costs.

To put the findings obtained in perspective, it should be noted that they apply independent of any specific motives for engaging in PEB, be it biophilia, altruism, prestige, or compliance with moral and social norms. They also apply to people's seeking satisfaction from contributing their own resources. Satisfaction from contributing one's own resources has been mentioned as a possible explanation for why more costly PEBs yield greater SWB (Schmitt et al. 2018). While possible, it is, however, not evident that the motive of "seeking satisfaction from contributing one's own resources" is associated with greater divergence between the decision-utility and experienced-utility weights – necessary for greater marginal SWB from a PEB to arise – than any other motive. If the SWB effects of a PEB are anticipated correctly, there will be no positive net marginal SWB in the first place – no matter if the PEB is costly or not.

Other explanations of positive net marginal SWB from PEB are reverse causation, corner solutions arising from additional constraints on PEB, and utility-SWB discrepancy (Welsch 2020).[8] The ability of the rational-choice decision-error framework to explain not only positive net marginal SWB but also its relationship with costs makes the framework an appealing contribution to our understanding of the effect of PEB on SWB.[9]

The analysis of this paper has highlighted the importance of the difference between decision-utility and experienced-utility weights for positive net marginal SWB to arise. With respect to this difference, an important implication of the analysis is that any factor that is associated with a greater decision-utility weight on PEB without being associated with a greater experienced-utility weight will imply a greater level of the PEB being carried out and lower net marginal SWB. Future empirical work may study whether stronger predictors of the level of a PEB (for instance a stronger moral norm, going with a greater PEB level) are associated with *less* marginal SWB – as is possible within the framework proposed in this paper but difficult to explain otherwise. Finding evidence of such cases may yield additional support for the validity of the proposed framework.

[8] Utility-SWB discrepancy involves the notion that people do not *fail* to maximize SWB, but do not *strive* to do so because SWB is just one of several arguments of the decision utility function (Benjamin et al. 2012).

[9] The empirical finding that the PEB-SWB relationship is stronger for more costly PEBs suggests that reverse causation cannot entirely explain the relationship: Why should the effect of "inherent" SWB on PEB be increasing in costs?

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Appendix: Proofs of Propositions 1 and 2 for CES utility functions with $\sigma \neq 1$

Proposition 1

The CES decision utility function takes the form

$$U(p, g, y) = (\alpha g^r + (1-\alpha)(y-pg)^r)^{1/r}, \quad \text{(A1)}$$

where $r = \frac{\sigma-1}{\sigma} < 1$ is positive for $\sigma > 1$ and negative for $\sigma < 1$.

Its experienced utility counterpart is

$$V(p, g, y) = (\beta g^r + (1-\beta)(y-pg)^r)^{1/r}. \quad \text{(A2)}$$

Similar to the Cobb-Douglas case, $\alpha \in (0,1)$ and $\beta \in (0,1)$ are the weights placed on a PEB relative to its conventional counterpart.

Maximization of the decision utility function yields the optimal levels of *g* and *c* (demand functions):

$$g^* = (\frac{\alpha}{p})^\sigma \frac{y}{\alpha^\sigma p^{1-\sigma}+(1-\alpha)^\sigma} \quad \text{(A3)}$$

$$c^* = y - pg^* = (1-\alpha)^\sigma \frac{y}{\alpha^\sigma p^{1-\sigma}+(1-\alpha)^\sigma}. \quad \text{(A4)}$$

These expressions correspond to the textbook CES demand functions observing that the price of *c* is unity (*c* is the numeraire).

Net marginal experienced utility is

$$W(g) := \frac{dV}{dg} = (\beta g^r + (1-\beta)(y-pg)^r)^{\frac{1}{r}-1}(\beta g^{r-1} - p(1-\beta)(y-pg)^{r-1}).$$

We wish to determine the sign of $W(g^*)$, that is $W(g)$ evaluated at g^*. We note that the expression $(\beta g^r + (1-\beta)(y-pg)^r)^{\frac{1}{r}-1}$ is always positive. We hence have:

$$sgn\, W(g^*) = sgn\, (\beta g^{*(r-1)} - p(1-\beta)(y - pg^*)^{r-1}).$$

Substituting g^* and y - $pg^* = c^*$ according to (A3) and (A4) and rearranging shows that

$$sgn\, W(g^*) = sgn\, A * (\beta (\frac{\alpha}{p})^{\sigma(r-1)} - p(1-\beta)(1-\alpha)^{\sigma(r-1)}),$$

where

$$A = (\frac{y}{\alpha^\sigma p^{1-\sigma} + (1-\alpha)^\sigma})^{-1} > 0.$$

Hence,

$$sgn\, W(g^*) = sgn(\beta (\frac{\alpha}{p})^{\sigma(r-1)} - p(1-\beta)(1-\alpha)^{\sigma(r-1)}).$$

Straightforward manipulations then show that

$$sgn\, W(g^*) = sgn\, (\beta - \alpha).$$

In sum, for CES utility functions with $\sigma \neq 1$ net marginal experienced utility at the decision-utility maximizing level of g is positive if and only if $\beta > \alpha$. Together with the result for Cobb-Douglas utility stated in the main text this establishes Proposition 1.

Proposition 2

We wish to determine the sign of the influence of the cost parameter, p, on $W(g^*)$. The costs affect $W(g^*)$ through their influence on g^* and c^* as follows: $\frac{dW(g^*)}{dp} = \frac{\partial W}{\partial g}\frac{\partial g^*}{\partial p} + \frac{\partial W}{\partial c}\frac{\partial c^*}{\partial p}$.

We note that $sgn\left(\frac{\partial W}{\partial g}\frac{\partial g^*}{\partial p} + \frac{\partial W}{\partial c}\frac{\partial c^*}{\partial p}\right) = sgn\, (\eta_{Wg}\varepsilon_{gp} + \eta_{Wc}\varepsilon_{cp})$, where $\eta_{Wg} = \frac{\partial lnW}{\partial lng}$, $\eta_{Wc} = \frac{\partial lnW}{\partial lnc}$, $\varepsilon_{gp} = \frac{\partial lng^*}{\partial lnp}$ and $\varepsilon_{cp} = \frac{\partial lnc^*}{\partial lnp}$ are elasticities (that turn out easier to handle than the corresponding derivatives).

We consider the elasticities in turn, starting with the elasticity of *c* with respect to *p*. Using (A4) we get

$$\varepsilon_{cp} = \frac{\partial lnc^*}{\partial lnp} = -\frac{(1-\sigma)\alpha^\sigma p^{1-\sigma}}{\alpha^\sigma p^{1-\sigma}+(1-\alpha)^\sigma} \qquad \text{(A5)}$$

The sign depends on σ; it is positive for $\sigma > 1$ and negative for $\sigma < 1$. This gives:

Lemma 1: $sgn\ \varepsilon_{cp} = sgn\ (\sigma - 1)$.

Using the definition $\sigma = -\frac{\partial \ln\left(\frac{g}{c}\right)}{\partial \ln p} = -\left(\frac{\partial \ln g}{\partial \ln p} - \frac{\partial lnc}{\partial lnp}\right)$ we get

$$\varepsilon_{gp} = \frac{\partial lng^*}{\partial lnp} = \varepsilon_{cp} - \sigma = -\frac{\alpha^\sigma p^{1-\sigma}+\sigma(1-\alpha)^\sigma}{\alpha^\sigma p^{1-\sigma}+(1-\alpha)^\sigma} \ ,$$

which is unambiguously negative. Hence we have

Lemma 2: $\varepsilon_{gp} < 0$.

By substituting $y - pg = c$ in (A2), we get

$$\eta_{Wg} = \frac{\partial lnW}{\partial lng} = (1-r)\left[\frac{\beta g^r}{\beta g^r+(1-\beta)c^r} - \frac{\beta g^{r-1}}{\beta g^{r-1}-p(1-\beta)c^{r-1}}\right],$$

where (1 – r) is positive by definition. The term $\beta g^{r-1} - p(1-\beta)c^{r-1}$, evaluated at g* and c*, can be shown to be positive if $\beta > \alpha$. Under the latter condition, η_{Wg}, evaluated at g* and c*, can be shown (using straightforward, but tedious manipulations) to be negative. Hence we have

Lemma 3: If $\beta > \alpha$, η_{Wg}, evaluated at g^* and c^*, is negative.

Finally, we get from (A2)

$$\eta_{WC} = \frac{\partial lnW}{\partial lnC} = (1-r)\left[\frac{(1-\beta)c^r}{\beta g^r + (1-\beta)c^r} + p\frac{(1-\beta)c^{r-1}}{\beta g^{r-1} - p(1-\beta)c^{r-1}}\right],$$

which is positive under $\beta > \alpha$. Hence,

Lemma 4: η_{Wc}, evaluated at $g*$ and $c*$, is positive if $\beta > \alpha$.

Combining Lemmas 1 – 4, we get that ($\sigma > 1$ and $\beta > \alpha$) implies $\frac{dW(g^*)}{dp} = \frac{\partial W}{\partial g}\frac{\partial g^*}{\partial p} + \frac{\partial W}{\partial c}\frac{\partial c^*}{\partial p} > 0$. Note that ($\sigma > 1$ and $\beta > \alpha$) is a sufficient, not a necessary condition for $\frac{dW(g^*)}{dp}$ to be positive. It could be positive for $\sigma < 1$, implying $\frac{\partial c^*}{\partial p} < 0$ (complementarity of *g* and *c*), if complementarity is sufficiently weak.

Together with the results for Cobb-Douglas utility stated in the main text, this establishes Proposition 2.

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